Synthesis of Indeno[1,2-*d*]azepine Derivatives

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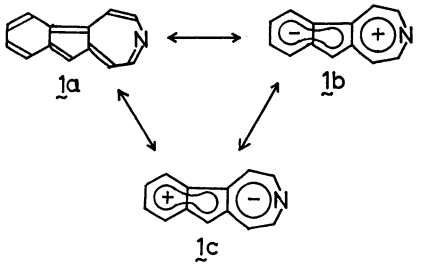
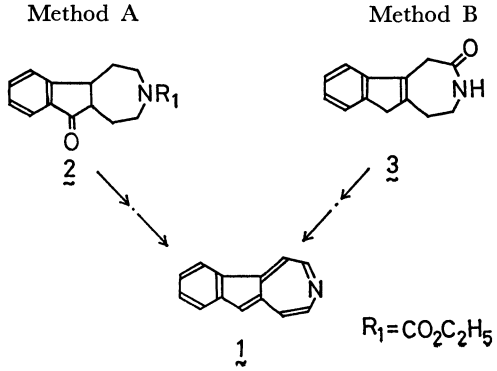
4-Ethoxyindeno[1,2-*d*]azepine(**18**) and 10-bromo-4-ethoxyindeno[1,2-*d*]azepine were prepared by *O*-ethylation of indeno[1,2-*d*]azepin-4-ol(**12ab**) and 10-bromoindeno[1,2-*d*]azepin-4-ol(**13ab**) with Et_3OBF_4 in 62 and 69% yields, respectively. **12ab** was obtained by bromination of 1,2,3,4,5,10-hexahydro-4-indeno[1,2-*d*]azepine(**3**) or 1,2,3,4-tetrahydroindeno[1,2-*d*]azepin-4-one with NBS, and subsequent dehydrobromination of the corresponding bromide formed *in situ* on basic alumina in 10% yield. When the bromination time was over 20 h, only **13ab** was isolated in 20% yield. Direct dehydrogenation of **3** with DDQ gave 10-chloroindeno[1,2-*d*]azepin-4-ol in 27% yield. The NMR and electronic spectra of **18** indicated the presence of a fully conjugated 14-pi ring system in it. We also investigated the possibility for dehydrogenation of 3-ethoxycarbonyl-1,2,3,4,5,5a,10,10a-octahydroindeno[1,2-*d*]azepin-10-one.

We have derived a simple synthetic approach for benz[*a*]azulene derivatives containing a nitrogen atom in the seven-membered ring that should lead to new theoretical and practical fields. Benz[*a*]azulene is a typical nonbenzeniod aromatic compound having two $(4n+2)$pi ring systems.[1] When an electron withdrawing >C=N– bond is introduced into part of the seven-membered ring, the stable 14-pi ring system may be destabilized by the contribution of a canonical structure like **1c**. As shown here, unconventional physical and



chemical properties can be anticipated to be associated with such molecules as **1abc**. Although there are five basic skeletones for azabenz[*a*]azulene, *i.e.*, indeno[2,1-*b*]-, indeno[2,1-*c*]-, indeno[1,2-*d*]-, indeno[1,2-*c*]-, and indeno[1,2-*b*]azepine, only 3-ethoxycarbonyl indeno[2,1-*b*]azepine(**4**) was prepared and studied by Treibs *et al.*[2] Furthermore, most of the reported azazulenes[3] to date, such as cyclopent[*c*]azepine,[3a] 6,7,8-triphenylcyclopent[*b*]azepine,[3b] and **4** have been prepared by the method using no dehydrogenation process to furnish the ring system. The development of a general synthesis of indenoazepines by dehydrogenation of the corresponding saturated ring system is desiable. We wish to report two independent methods (methods A and B) utilized in the preparation of **1** by the use of **2** and **3**. In method A, we investigated the possibility for dehydrogenation of **2**. In method B, we wish to report the successful synthesis of novel **18** from **3**.



Results and Discussion

Method A. Some Attempts for Dehydrogenation of **2**: This method was characterized by the use of **2**, the structure of which was established.[4] Mono- and dibromination of **2** were effected with 1 equiv of bromine in ether solution. Upon dehydrobromination of the corresponding bromides using lithium chloride in DMF at 120 °C, there was a yellow oil obtained. Preparative column chromatography of the reaction mixture on silica gel permitted purification and isolation of 3-ethoxycarbonyl-1,2,3,4,5,10-hexahydroindeno[1,2-*d*]-azepin-10-one(**5**), and 3-ethoxycarbonyl-1,2,3,10-tetrahydroindeno[1,2-*d*]azepin-10-one(**6**). The structures of **5** and **6** were deduced from the following NMR, IR, electronic spectra, and elemental analyses. An elemental analysis suggested that **5** was formulated as $C_{16}H_{17}NO_3$ and **6** was $C_{16}H_{15}NO_3$. Therefore a new double bond and two double bonds were introduced into **2**, and **5** and **6** were prepared, respectively. The electronic spectrum of the yellow compound **5** showed strong absorption bands at 237 (log ε, 4.54) and 244 nm (4.55). This absorption pattern was similar to that of 8-methyl-1,2,3,4-tetrahydrofluoren-9-one(**7**).[10] In NMR spectrum of **5**, the resonances of methylene groups appear at 2.45—2.49 (4H, m) and 3.45—3.88 ppm (4H, m). These results support the structure of **5**. The electronic spectrum of the red compound **6** showed three absorption bands at 224 (log ε, 4.22), 277 (4.34), and 455 nm (2.93). In NMR spectrum of **6**, the resonances of methylene groups appear at 2.88 (2H, t, J=4.5 Hz), and the resonances at 5.75 (1H, d, J=9.1 Hz) and 7.02 ppm (1H, d, J=9.1 Hz)

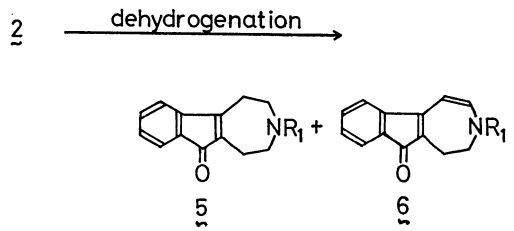


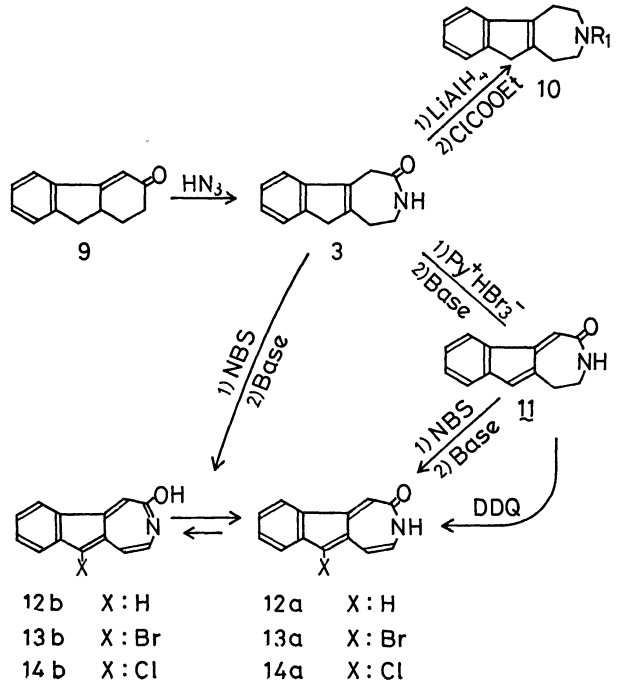
Table 1. Summary of Method A

Starting azepine	Reaction conditions: Dehydrogenation agent (Solvent/temp, °C/time)		Products and their yield (%) 5	6
2	1) Br_2	(Ether/0/20 min)	31.5	5.2
	2) LiCl	(DMF/120/7 h)		
2	DDQ	(Dioxane, N_2/Reflux/53 h)	31.0	11.0
2	Pd/C	(Decalin, N_2/Reflux/190/53 h)	3.4	2.6
2	Ph_3CBF_4	(CH_3COOH, Ar/Reflux/8.5 h)	—	8.6
5	DDQ	(Dioxane, Ar/Reflux/9 h)	Polymers	
5	Ph_3CBF_4	(CH_3COOH, N_2/Reflux/14 h)		17.0

7 8

are corresponding to γ and δ protons of $\alpha,\beta,\gamma,\delta$-unsaturated ketone system in **6**. These results support the structure of **6**. The results of bromination and subsequent dehydrobromination of **2** are summarised in Table 1. Allylic bromination of both **5** and **6** were achieved with 1 equiv of NBS in the presence of a catalytic amount of bezoyl peroxid. The dehydrobrominations of the corresponding bromides with LiCl in DMF produced a complex and tarry mixture. Similarly, the dehydrogenation of **5** and **6** with DDQ produced a complex and tarry mixture. In the case of dehydrogenation of **5** with triphenylmethyl tetrafluoroborate, **6** was isolated by preparative TLC. Dehydrogenation of **6** with triphenylmethyl tetrafluoroborate gave no evidence for the formation of **8**. It thus became necessary to develop another method for preparing **1** by the use of more stable intermediates.

Method B. *Synthesis of **18** and **19** from **3***: Considering the difficulty of the preparation of a fully conjugated azepine system from hydroazepine(**2**), we chose **3** as an intermediate into which introduction of >C=N– bond was accomplished with the aid of tautomerism between the lactam form (**12a**) and azepinol form (**12b**). The reaction sequence is outlined in Scheme 1. The ring expansion of 1,2,3,9a-tetrahydrofluoren-3-one (**9**)[5] with sodium azide in PPA at 40 °C, followed by column chromatography on neutral alumina produced **3** in 60% yield. For the confirmation of the structure, **3** was treated successively with $LiAlH_4$ and ethyl chloroformate. The expected 1-ethoxycarbonyl-1,2,3,4,5,10-hexahydroindeno[1,2-*d*]azepine (**10**: R=$CO_2C_2H_5$) was obtained in 80% yield. **10** was identified by comparison with the NMR and IR data of the authentic sample obtained by Kimura and Morosawa.[4a] Bromination of **3** with 1.1 molar equiv of pyridinium hydrogenbromide perbromide in acetic acid at 40 °C for 4 h,



Scheme 1.

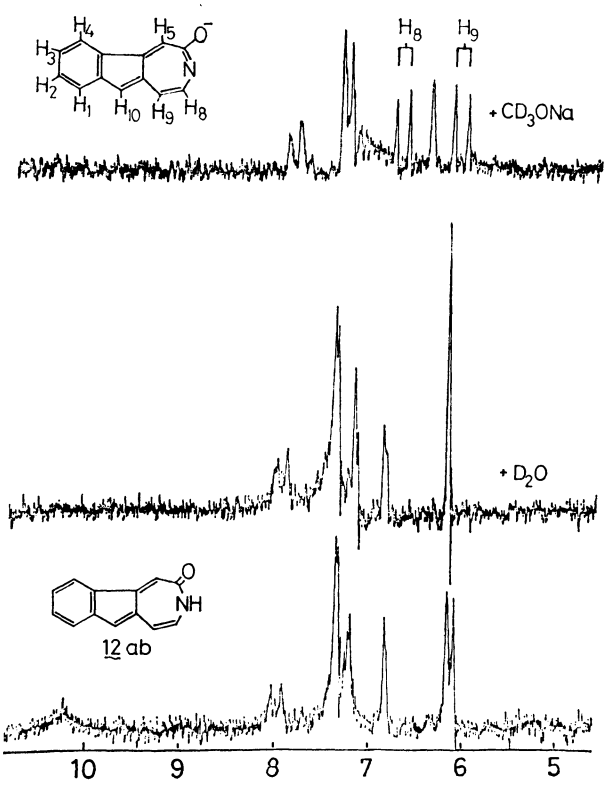


Fig. 1. NMR spectra of **12ab** in DMSO-d_6 (bottom), in the presence of few drops of D_2O (middle), and in the presence of 1 equiv of CD_3ONa (top).

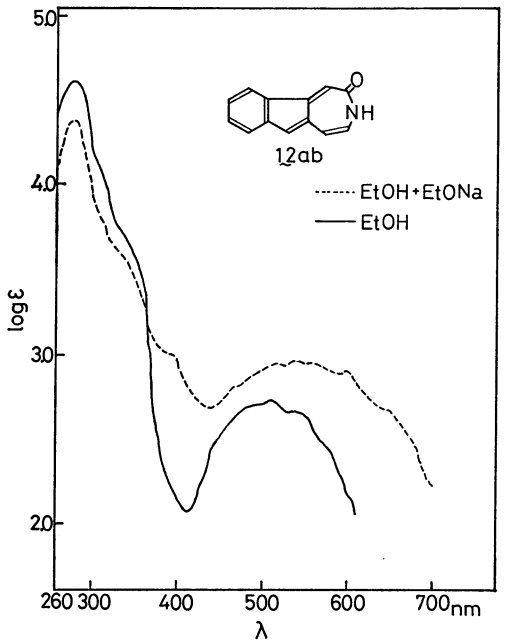


Fig. 2. Electronic spectra of **12ab** in EtOH (——) and in the presence of 1 equiv of EtONa (----).

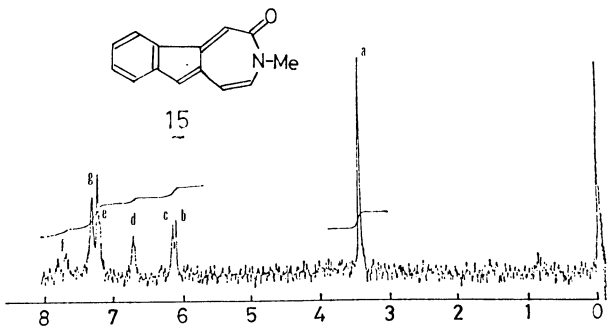


Fig. 3. NMR spectrum of **15** in $CDCl_3$.

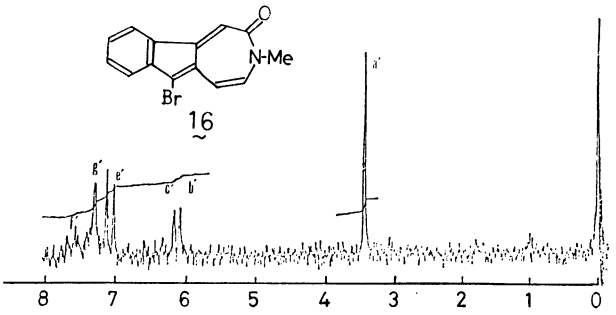
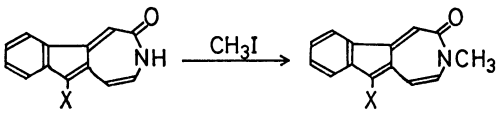


Fig. 4. NMR spectrom of **16** in $CDCl_3$.

followed by dehydrobromination of the corresponding bromide on basic alumina, produced a yellow-orange solid **11** in 83% yield. Bromination of **11** with 1.1 molar equiv of NBS in refluxing benzene in the presence of a catalytic amount of benzoyl peroxide for 10 h, followed by dehydrobromination of the corresponding bromide formed *in situ* on basic alumina, produced **12ab** in 10% yield. The NMR spectrum of the reddish purple solution of **12ab** in DMSO-d_6 showed resonance peaks at 6.25 (2H), 7.40 (1H), 7.20—7.60 (4H), 7.95 (1H), and 10.25 ppm (1H). When a few drops of D_2O were added to the solution, the resonance peak at 6.25 ppm became pseudo singlet and the resonance peak at 10.25 ppm disappeared. The resonance peak at 6.25 ppm became a pair of doublet peaks at 6.05 (1H, d, J=9 Hz, H_9) and 6.75 ppm (1H, d, J=9 Hz, H_8) with the addition of 1 equiv of CD_3ONa (shown in Fig. 1). On the basis of these findings the resonance peak at 6.25 ppm may be assigned to the adjacent 8- and 9-protons of **12ab**. The IR spectrum of **12ab** showed absorptions at 3200 and 1650 cm^{-1} for >NH and >C=O streching of the amide group, respectively. The electronic spectrum of **12ab** in EtOH showed absorptions at λ_{max} 510 (log ε, 2.9), 345(sh), 283 nm(4.7). When 1 equiv of EtONa was added to the solution, the absorptions shifted to a longer wavelength by $\approx$50 nm (shown in Fig. 2). The bathochromic shift in basic solution was attributable to the substantial enhancement of the double bond character of the >N(CO)– bond by the removal of the amide proton.[6]

When the refluxing time of the bromination of **3** with NBS was over 20 h, **13ab** was obtained in a 20% yield. On the other hand, the direct dehydrogenation of **3** with DDQ in refluxing benzene for 20 h, followed by chromatography on silica gel eluting with CH_2Cl_2, produced purple solids **14ab** in 20% yield. The reaction mechanisms for the formation of these unexpected products (**13ab** and **14ab**) were now under-investigation. **3** and **11** showed strong infrared absorptions at 1670 and 1650 cm^{-1}, respectively, as streching for each amide's carbonyl in their lactam rings occured. Both **13ab** and **14ab**, however, showed medium infrared absorptions at 1640 cm^{-1} as streching for the amide's carbonyl in their lactam rings occured. The electronic spectra of **13ab** and **14ab** were similar to that of **12ab**. The possition of X in **13ab** and **14ab** (Scheme 1) was determined in the following discussion.

N-Methylation of **12ab**, **13ab**, and **14ab** using an excess of 40% NaOH and CH_3I with a trace of benzyltriethylammonium chloride under phase-transfer conditions[7] at room temperature for 12 h produced high yields of **15**, **16**, and **17**, respectively. The assignment



12ab	X:H	15	X:H
13ab	X:Br	16	X:Br
14ab	X:Cl	17	X:Cl

of the position of entry of the bromine atom was determined by the comparison between NMR spectra **15** and **16** in the presence of a shift reagent ($Eu(fod)_3$). The NMR spectra of **15** and **16** are shown in Figs. 3 and 4. Figures 5 and 6 show plots of the induced shifts *vs.* the shift reagent/substrate mole ratios (E/S) for the substrates **15** and **16**, respectively. In Figs. 3 and 4, the absorption labeled by a and a′ are assigned to methyl groups of **15** and **16** in terms of their integrations and chemical shifts of 3.50 and 3.45 ppm, re-

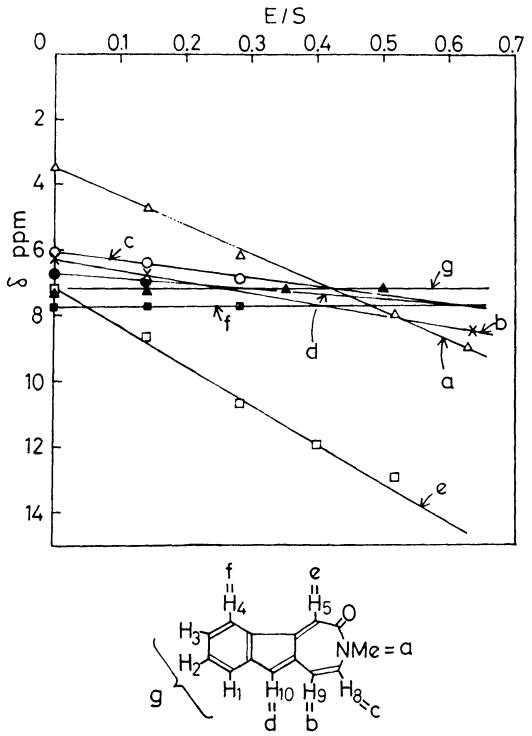


Fig. 5. δ *vs.* E/S for **15** with $Eu(fod)_3$ in $CDCl_3$.

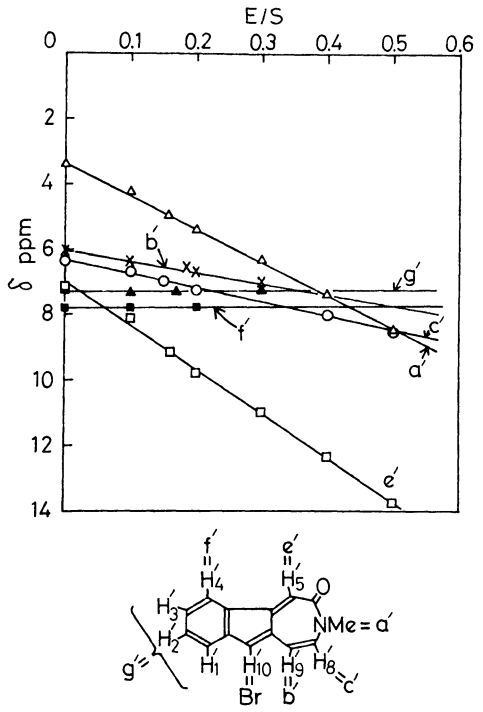


Fig. 6. δ *vs.* E/S for **16** with $Eu(fod)_3$ in $CDCl_3$.

spectively. The sizable shifts observed in their methyl protons nearest to their carbonyl groups indicate association through their carbonyl groups. The shifts of vinyl protons e and e′ were greater than the other vinyl protons in Figs. 5 and 6, respectively. Each of these should be assigned to H_5 and H_5' where the positions are nearest to each carbonyl group. Two couples of their resonances of f and g, and f′ and g′ were assigned to each benzene ring, due to the lack

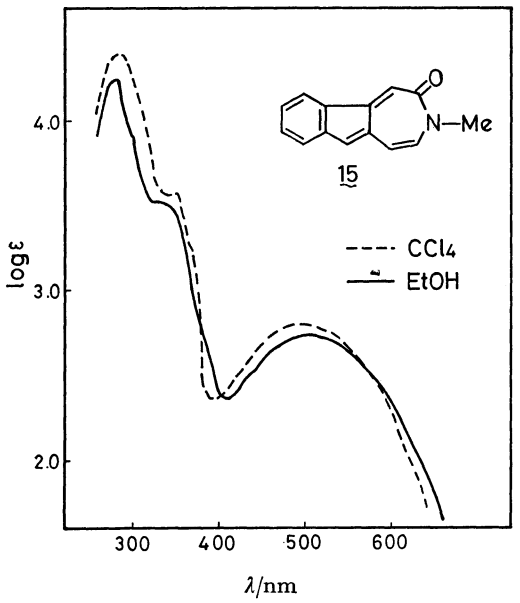


Fig. 7. Electronic spectra of **15** in EtOH (——) and in CCl_4 (----).

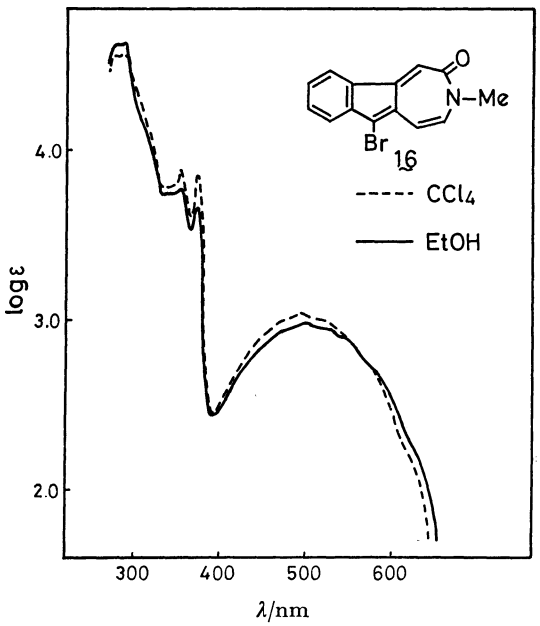


Fig. 8. Electronic spectra of **16** in EtOH (——) and in CCl_4 (----).

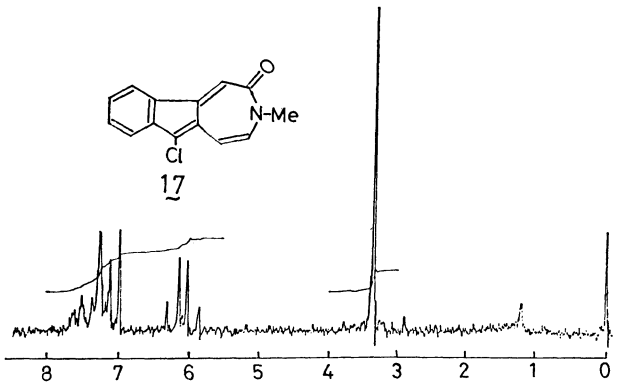


Fig. 9. NMR spectrum of **17** in $CDCl_3$.

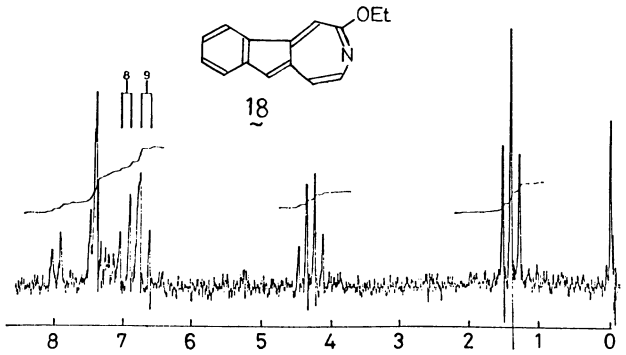


Fig. 10. NMR spectrum of **18** in CCl_4.

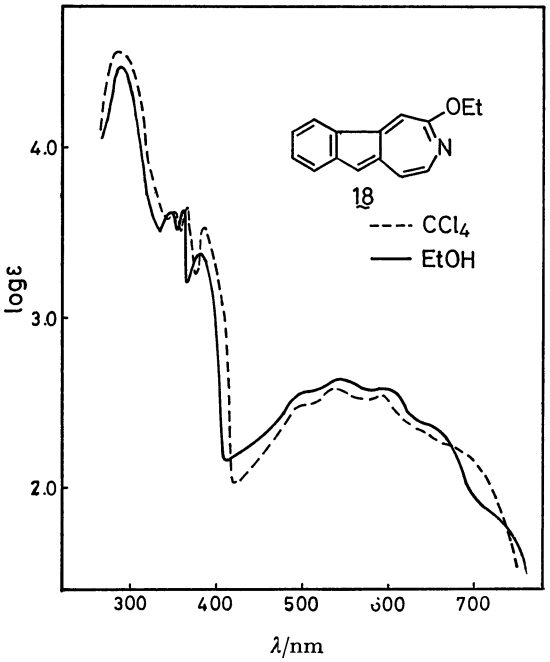


Fig. 11. Electronic spectra of **18** in EtOH (——) and in CCl_4 (----).

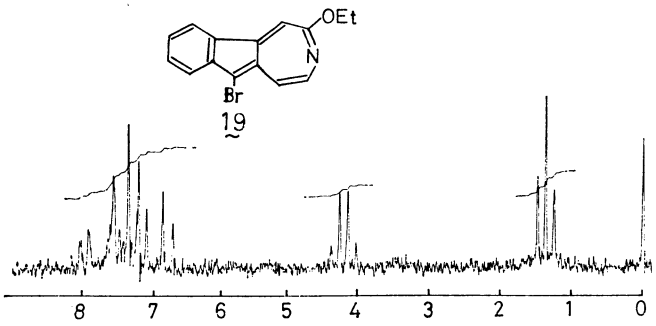


Fig. 12. NMR spectrum of **19** in $CDCl_3$.

of shifts up to equimolar ratios of **15** to $Eu(fod)_3$ and of **16** to $Eu(fod)_3$. Two pairs of b and c, and b′ and c′ were assigned to H_8 and H_9, and H_8' and H_9', respectively, with each coupling constant $J=10$ Hz. In Figs. 4 and 6, lack of the resonance corresponding to H_{10}' indicated that the position was substituted by bromine atom. The electronic spectra of **15** and **16** are shown in Figs. 7 and 8, respectively. Com-

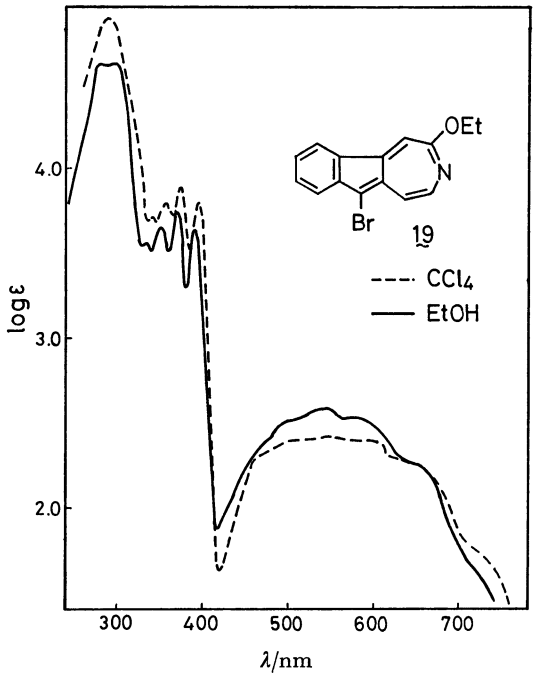
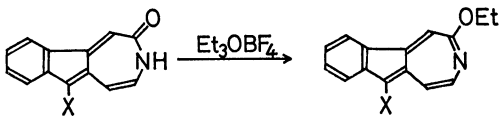


Fig. 13. Electronic spectra of **19** in EtOH (——) and in CCl_4 (----).

parison of NMR spectrum of **17** with that of **16** revealed that the position of the entry of the chlorine atom to the indeno[1,2-*d*]azepine ring was the same as that of the bromine atom in **16** (see Figs. 4 and 9).

O-Ethylation of **12ab** and **13ab** with triethyloxonium tetrafluoroborate[8] led to the isolation of the novel 4-ethoxyindeno[1,2-*d*]azepine (**18**) and 10-bromo-4-ethoxyindeno[1,2-*d*]azepine(**19**) in 53 and 60% yields,



12ab X:H
13ab X:Br

18 X:H
19 X:Br

respectively. These compounds were found to be labile by treatment with base, and had to be handled with care to avoid decomposition during chromatography on alumina.[9] Their structures followed from their spectral characteristics. IR showed 1640 and 1585 cm^{-1} as representative of the streching of the >C=N– and >C=C< bonds, respectively. In Fig. 10 the resonance of hydrogens H_8 and H_9 appears at lower fields than those of **15** by ≈1.00 ppm. This deshielding of the ring protons in **18** indicated the aromatic character of the 14-pi ring system supporting diamagnetic anisotropy. The electronic spectrum of **18** in CCl_4 (Fig. 11) was similar to that of benz[*a*]azulene itself.[1a,4b] The longest absorption band of **18** shifted to a longer wavelength by ≈50 nm than that of **15** (see Figs. 7 and 11). These results also indicated the presence of a fully conjugated 14-pi ring system in **18**. **19** showed similar characteristics on NMR and electronic spectra to that of **18** (Figs. 12 and 13).

Experimental

The structures of all the new compounds were cofirmed by NMR, IR, UV, and elemental analyses. All melting points and boiling points are uncorrected. IR(nujol) spectra were determined on a JASCO IR A-1 grating infrared spectrometer. NMR($CDCl_3$/TMS, Hitachi-Perkin Elmer R-20) spectra were obtained at 60 MHz unless otherwise noted. The chemical shifts are represented in terms of δ values. UV(Hitachi UV-200) spectra were obtained in terms of nm. Column chromatography and TLC were performed using Wakogel C-200, and Kieselgel 60F 254 respectively. **2** and **9** were prepared by the method developed by M. Kimura and S. Morosawa,[4a] and E. Bergmann *et al.*[5] respectively. Triphenylmethyl tetrafluoroborate was prepared by the procedure developed by H. J. Dauben, Jr., *et al.*[11]

*3-Ethoxycarbonyl-1,2,3,4,5,10-hexahydroindeno[1,2-*d*]azepin-10-one(**5**) and 3-Ethoxycarbonyl-1,2,3,10-tetrahydroindeno[1,2-*d*]azepin-10-one(**6**).* To a stirring solution of 3-ethoxycarbonyl-1,2,3,4,5,5a,10,10a-octahydroindeno[1,2-*d*]azepin-10-one (**2**, 490 mg, 1.7 mmol) in 25 ml of ether was added a solution of bromine (310 mg, 1.9 mmol) in CCl_4 over a period of 20 min at 0 °C. After stirring for additional 10 min at room temperature, the solution was washed with 10% aqueous $NaHSO_3$, and 5% aqueous $NaHCO_3$ and dried over $MgSO_4$. The solvent was removed to give a yellow oil (670 mg). The viscous slightly yellow bromide was employed without further purification. A suspension of LiCl (720 mg, 1.7 mmol) and the crude bromide (600 mg, 1.7 mmol) in 15 ml of dry THF was heated at 120 °C for 7 h under a nitrogen atmosphere. After being cooled to room temperature, the solvent was removed *in vacuo*, and the residue was taken up in benzene. The solution was washed with saturated aqueous NaCl solution, and the solvent was removed to give a brown oil. The oil was chromatographed on silica gel (benzene as eluent) to give 21.3 mg(5.3%) of **7**, 129.3 mg(31%) of **5**. **5**: IR(KBr) 1703, 1694, 1621, 1603, 1595 cm^{-1}; NMR 1.28 (3H, t, J=7.1 Hz), 2.43—2.94 (4H, m), 3.45—3.88 (4H, m), 4.22 (2H, q, J=7.1 Hz), 6.93—7.68 ppm (4H, m); UV λ_{max} (EtOH) 237 (log ε, 4.54), 244 (4.55), 305 (2.95). Found: C, 70.74; H, 6.52; N, 4.97%. Calcd for $C_{16}H_{17}NO_3$: C, 70.83; H, 6.32; N, 5.16%. **6**: IR(KBr) 1700, 1690, 1606, 1590 cm^{-1}: NMR 1.33 (3H, t, J=7.1 Hz), 2.88 (2H, t, J=4.5 Hz), 3.92 (2H, t, J=4.5 Hz), 5.75 (1H, d, J=9.1 Hz), 7.02 (1H, d, J=9.1 Hz), 6.88—7.88 ppm (4H, m); UV λ_{max} (EtOH) 224 (log ε, 4.22), 277 (4.34), 455 (2.93). Found: C, 71.06; H, 5.61; N, 4.97%. Calcd for $C_{16}H_{15}NO_3$: C, 71.36; H, 5.61; N, 5.20%.

*Dehydrogenation of 3-Ethoxycarbonyl-1,2,3,4,5,5a,10,10a-octahydroindeno[1,2-*d*]azepin-10-one(**2**) with DDQ.* A solution of **2** (50 mg, 0.183 mmol) and DDQ (138 mg, 0.549 mmol) in 1 ml of dry dioxane was refluxed for 53 h under a nitrogen atmosphere. After cooling to room temperature, the solvent was removed to give a brownish residue. The residue was separated with TLC (silica gel, 50% ether in benzene) to give **6** (5.4 mg, 11%, R_f (silica gel, benzene/ether=1:1)= 0.61), **5** (15.6 mg, 31%, R_f=0.47), and **2** (17.3 mg, 35% recovered, R_f=0.38). These products were identified by comparison of their R_f values and UV data with those of each authentic sample.

*Dehydrogenation of **2** with Pd/C.* A suspension of **2** (500 mg, 1.83 mmol) and 8%-Pd/C (500 mg) in 4 ml of dry decalin was refluxed for 53 h under a nitrogen atmosphere. After cooling to room temperature, the Pd/C was filtered off and the filtrate was passed through short column (silica gel, eluting with benzene). Removing the solvent under reduced pressure, 390 mg of red oil was remained. The residue was chromatographed using a silica gel column with 50% ether in benzene as eluent. From first fraction, 8.3 mg of **6** was collected, and 7.3 mg of **5** was collected from second fraction. **5** and **6** were identified by the method shown in preceeding experiment.

*Dehydrogenation of **2** with Triphenylmethyl Tetrafluoroborate.* A mixture of **2** (20 mg, 0.073 mmol) and triphenylmethyl tetrafluoroborate (26.6 mg, 0.081 mmol) in 2 ml of dry acetic acid was refluxed for 8.5 h under an argon atmosphere. Additional 24.2 mg (0.073 mmol) of triphenylmethyl tetrafluoroborate was added and the brown solution was refluxed for additional 4.5 h under the same conditions. After cooling to room temperature, the solvent was removed under reduced pressure, and a brown residue was poured into water and extracted with ether. The ethereal extract was dried over Na_2SO_4. After removing the solvent, brown oil (16.4 mg) was obtained. This oil was chromatographed on silica gel eluting with 5% ether in benzene to give **6** (1.7 mg, 8.6%) and **2** (6.3 mg, 32%). **2** and **6** were identified by the method shown in preceeding experiment.

*Dehydrogenation of **5** with DDQ.* A solution of **5** (20 mg, 0.074 mmol) and DDQ (98%, 18.8 mg, 0.081 mmol) in 2 ml of dry dioxane was refluxed for 9 h under an argon atmosphere. Additional DDQ (17.1 mg, 0.074 mmol) was added to the mixture and the solution was refluxed for another 24.5 h. After usual workup, **5** was recovered.

*Dehydrogenation of **5** with Triphenylmethyl Tetrafluoroborate.* A solution of **5** (20 mg, 0.074 mmol) and triphenylmethyl tetrafluoroborate (51.1 mg, 0.16 mmol) in dry acetic acid was refluxed for 14 h under a nitrogen atmosphere. After usual workup, **6** (3.4 mg, 17%) was obtained and **5** (12.9 mg, 65%) was recovered. **5** and **6** were identified by the method shown in preceeding experiment.

*Dehydrogenation of **6** with DDQ.* A solution of **6** (5.0 mg, 0.019 mmol) and DDQ (13.0 mg, 0.056 mmol) in 3 ml of dry dioxane was refluxed under an argon atmosphere. The reaction was monitored by TLC and the starting material was completely disappered after 17 h. Some uncharacterized polymer was obtained.

*Dehydrogenation of **6** with Triphenylmethyl Tetrafluoroborate.* A solution of **6** (5.0 mg, 0.019 mmol) and triphenylmethyl tetrafluoroborate (12.3 mg, 0.037 mmol) in 2 ml of dry acetic acid was refluxed under an argon atmosphere and the reaction was monitored by TLC. No reaction was observed up to 6.5 h and only **6** was recovered.

*1,2,3,4,5,10-Hexahydroindeno[1,2-*d*]azepin-4-one (**3**).* To a stirring mixture of **9** (3.58 g, 0.036 mol) and phosphorus pentaoxide (1.7 g, 0.012 mol) in 600 g of polyphosphoric acid (105%) was added in portions sodium azide (3.5 g, 0.054 mol) over 1 h at 40—50 °C and the reaction mixture was stirred for 48 h at same temperature. After cooling to room temperature, the reaction mixture was poured onto ice–water, and extracted with chloroform. The extract was washed with 5% aqueous $NaHCO_3$, then with water, and was dried over $MgSO_4$. The residue obtained on evaporation of the solvent was solidified to give an orange solid (2.7 g, 70%). The solid was subjected to column chromatography on neutral alumina eluting with CH_2Cl_2 to give **3** (2.3 g, 60%): pale yellow prisms from C_2H_5OH, mp 207—209 °C; IR 3250, 1670 cm^{-1}; UV λ_{max} (EtOH) 207 (log ε, 4.28), 260 (4.01); NMR(CCl_4) 2.50—2.90 (2H, m), 3.28 (2H, bs), 3.45—3.75 (4H, m), 7.00—7.60 (5H, m, aromatic H and NH). Found: C, 78.21; H, 6.51; N, 7.10%. Calcd for $C_{13}H_{13}NO$: C, 78.36; H, 5.58; N, 7.03%.

*3-Ethoxycarbonyl-1,2,3,4,5,10-hexahydroindeno[1,2-*d*]azepine (**10**).* A suspension of $LiAlH_4$ (0.72 g, 19 mmol) in

40 ml of dry THF was stirred and refluxed for 1 h. After cooling on an ice bath, a solution of **3** (1.5 g, 7.5 mmol) in dry THF (100 ml) was added dropwise over a period of 1 h. After addition was complete, the mixture was stirred 24 h at room temperature. A sufficient amount of 3 N aqueous hydrochloric acid (10 ml) was carefully added dropwise to decompose excess $LiAlH_4$. The acidified solution was workup immediately by extraction with ether. To the ether extract was added 3% aqueous potassium carbonate (30 ml), and ethyl chloroformate (3.8 g, 35 mmol). After stirring for 1 h, the ether layer was separated. The ether was removed and the residue was distilled under reduced pressure to give the indene **10** (1.63 g, 80%), bp 214—217 °C/0.2 Torr. **10** was identified by comparison of IR and NMR spectra with those of authentic sample obtained by M. Kimura and S. Morosawa.[4a]

*1,2,3,4-Tetrahydroindeno[1,2-*d*]azepin-4-one* (**11**). A solution of **3** (100 mg, 0.50 mmol) and pyridinium hydrogenbromide perbromide (192 mg, 0.6 mmol) in 15 ml of dry acetic acid (passed through alumina) was heated at 40 °C for 6 h. The residue obtained on evaporation of the solvent was taken up in chloroform. Column chromatography on alumina eluting with chloroform gave **11** (60 mg, 61%): orange prisms from CH_2Cl_2, mp 201 °C; IR 3180, 1650, 1600(sh) cm^{-1}; UV λ_{max} (EtOH) 260 (log ε, 4.5), 330 (3.9), 380(sh); NMR (DMSO-d_6) 2.60—3.00 (2H, m), 3.10—3.50 (2H, m), 6.69 (2H, bs), 7.20 (3H, m), 7.65 (1H, bs), 8.10 (1H, m). Found: C, 79.10; H, 5.89; N, 6.96%. Calcd for $C_{13}H_{11}NO$: C, 79.16; H, 5.62; N, 7.10%.

*Indeno[1,2-*d*]azepin-4-ol* (**12ab**). 1) A solution of **3** (5 g, 26 mmol), NBS (5.1 g, 29 mmol), and benzoyl peroxide (100 mg, 0.41 mmol) was refluxed at 45 °C for 24 h. The reaction mixture was chromatographed on alumina eluting with 4% ethanol in CH_2Cl_2 to give **11** (2.0 g, 40%) and **12ab** (502 mg, 10%). **12ab**: black fine prisms from CH_2Cl_2, mp 240 °C (sublimed); IR 3200, 1650 cm^{-1}; UV λ_{max} (EtOH) 283 (log ε, 4.7), 345 (sh), 510(2.9); NMR (DMSO-d_6) 6.25 (2H, m), 6.40 (1H, s), 7.10—7.20 (4H, m), 7.95 (1H, d), 10.25 (1H, m). Found: C, 79.63; H, 4.43; N, 6.76%. Calcd for $C_{13}H_9NO$: C, 79.98; H, 4.65; N, 7.17%. **11** was identified by comparison of IR and NMR spectra with those of authentic sample obtained in preceeding experiment. 2) A solution of **11** (200 mg, 1.0 mmol) and NBS (180 mg, 1.0 mmol) in benzene was refluxed in the presence of a catalytic amount of benzoyl peroxide for 4.5 h. After cooling to room temperature, the reaction mixture was passed through alumina eluting with CH_2Cl_2, removed the solvent to give a black solid. Recrystallization of the solid from THF gave **12ab** (20 mg, 10%). **12ab** was identified by comparison of its IR and NMR spectra with those of authentic sample obtained in preceeding experiment.

*10-Bromoindeno[1,2-*d*]azepin-4-ol* (**13ab**). A solution of **11** (100 mg, 0.51 mmol) and NBS (100 mg, 0.56 mmol) in CH_2Br_2 was refluxed at 120 °C (bath temperature) in the presence of a catalytic amount of benzoyl peroixide for 24 h. After usual workup, **13ab** (60 mg, 43%) was obtained: black fine hair like needles from THF, mp 320 °C dec; IR 3200, 3130, 1675, 1638, 1615, 1600 cm^{-1}; NMR (DMSO-d_6) 6.00—6.55 (2H, m), 7.22—7.60 (4H, m), 8.00—8.25 (1H, m), 10.30—10.50 ppm (1H, bs); UV λ_{max} (EtOH) 286 (log ε, 4.7), 350(sh), 368(sh), 500(3.0). Found: C, 56.87; H, 2.88; N, 4.82%. Calcd for $C_{13}H_8NOBr$: C, 56.96; H, 2.94; N, 5.11%.

*10-Chloroindeno[1,2-*d*]azepin-4-ol* (**14ab**). A solution of **11** (1.6 g, 8.1 mmol) and DDQ (5.5 g, 24 mmol) in dry dioxane was refluxed for 24 h under a nitrogen atmosphere. After cooling to room temperature, the reaction mixture was filtered and passed through short alumina column eluting with $CHCl_3$. After removing the solvent, the residue was column chromatographed on alumina eluting with CH_2Cl_2 to give **14ab** (530 mg, 28%): black hair like needles from THF, mp 260 °C dec; IR 3200, 3130, 1675, 1640, 1620, 1598 cm^{-1}; NMR (DMSO-d_6) 6.05—6.50 (2H, m), 7.20—7.70 (4H, m), 8.25—8.95 (1H, m), 10.20—10.60 ppm (1H, m); UV λ_{max} (EtOH) 285 (log ε, 4.7), 350(sh), 368(sh), 515 (2.9). Found: C, 67.69; H, 3.27; N, 5.75%. Calcd for $C_{13}H_8NOCl$: C, 67.99; H, 3.51; N, 6.10%.

*3-Methylindeno[1,2-*d*]azepin-4-one* (**15**). To a 50% aqueous solution of NaOH (5 ml) was added a solution of **12ab** (30 mg, 0.15 mmol) and benzyltriethylammonium chloride (41 mg, 0.18 mmol). After 15 min stirring at room temperature, 52 mg of MeI (0.36 mmol) was added to the suspension. The reaction mixture was stirred for 40 min at room temperature. Organic layer was separated, washed with water, and dried over $MgSO_4$. The residue obtained by evaporation of the solvent was recrystallized from ethanol to give **15** (30 mg, 95%): brown needles from CH_2Cl_2, mp 149—150 °C; IR 1628, 1620, 1600(sh) cm^{-1}; UV λ_{max} (EtOH) 275 (log ε, 4.2), 330(sh), 505(2.9); NMR 3.50 (3H, s), 6.09 (1H, d, J=9 Hz), 6.29 (1H, d, J=9 Hz), 6.80 (1H, s), 7.29 (1H, s), 7.20—7.55 (3H, m, aromatic H), 7.82 ppm (1H, bs, aromatic H). Found: C, 80.01; H, 5.27; N, 6.71%. Calcd for $C_{14}H_{11}NO$: C, 80.36; H, 5.30; N, 6.69%.

*10-Bromo-3-methylindeno[1,2-*d*]azepin-4-one* (**16**). The reaction was carried out as described for the preparation of **14ab**. The crude product was purified by recrystallization from CH_2Cl_2: **16**, 95% yield, dark brown needles, mp 154—156 °C; IR 1655, 1640(sh), 1605(sh), 1598 cm^{-1}; UV λ_{max} (EtOH) 280 (log ε, 4.64), 354 (3.76), 372(3.66), 500 (2.98); NMR 3.42 (3H, s), 6.05 (1H, d, J=10 Hz), 6.35 (1H, d, J=10 Hz), 7.05 (1H, s), 7.22—7.62 (3H, m, aromatic H), 7.75 ppm (1H, bd, aromatic H). Found: C, 68.48; H, 3.91; N, 5.47%. Calcd for $C_{14}H_{10}NOCl$: C, 69.00; H, 4.14; N, 5.75%.

*10-Chloro-3-methylindeno[1,2-*d*]azepin-4-one* (**17**). The crude product, obtained in a similar way used for **14ab**, was crystallized from CH_2Cl_2: **17**, 95% yield, dark brown needles, mp 160—160.5 °C; IR 1652(sh), 1640, 1603(sh), 1596 cm^{-1}; UV λ_{max} (EtOH) 277 (log ε, 4.66), 330 (3.82), 345(3.75), 490(3.08); NMR 3.45 (3H, s), 6.10 (1H, d, J=10 Hz), 6.45 (1H, d, J=10 Hz), 7.20 (1H, s), 7.20—7.60 (3H, m, aromatic H), 7.75 ppm (1H, bs, aromatic H). Found: C, 58.45; H, 3.27; N, 4.85%. Calcd for $C_{14}H_{10}NOBr$: C, 58.36; H, 3.50; N, 4.86%.

*4-Ethoxyindeno[1,2-*d*]azepine* (**18**). In a dry 20 ml two-necked flask protected from atmospheric moisture was placed a solution of freshly redistilled boron trifluoride etherate (74 μl, 0.58 mmol) in 2 ml of anhydrous ether. Epichlorohydrin (36 μl, 0.45 mmol) was added dropwise at 40 °C. When the epichlorohydrin had been added, the oil which initially formed began to solidify. The mixture was stirred at room temperature for 2 h, and the solvent was decanted. The triethyloxonium tetrafluoroborate was washed well with anhydrous ether and dissolved in 1.5 ml of dry CH_2Cl_2. This solution was stirred at 10—15 °C while a solution of **12ab** (20 mg, 0.10 mmol) in 2 ml of dry CH_2Cl_2 was added dropwise. The resulting solution was stirred at room temperature for 12 h. To the stirred solution was cautiously added 2 g of a 50% aqueous potassium carbonate solution. After separation of CH_2Cl_2 layer, the solution was washed with water, and dried over $MgSO_4$. The solution was passed through silica gel to give crude **18** (14 mg, 62%): purple

fine needles from CH_2Cl_2, mp 115—117 °C; IR 1640, 1585 cm^{-1}; UV λ_{max} (EtOH) 288 (log ε, 4.5), 345(3.6), 361 (3.6), 382(3.5), 544(2.6); NMR(CCl_4) 1.38 (3H, t, J= 7 Hz), 4.29 (2H, q, J=7 Hz), 6.73 (1H, d, J=9 Hz), 6.82 (1H, s), 7.03 (1H, d, J=9 Hz), 7.15—7.60 (3H, m, aromatic H), 7.45 (1H, s), 8.07 (1H, d, aromatic H). Found: C, 80.50; H, 6.64; N, 6.17%. Calcd for $C_{15}H_{13}NO$: C, 80.69; H, 8.87; N, 6.27%.

*10-Bromo-4-ethoxyindeno[1,2-d]azepine (**19**).* The crude product, obtained in a similar way used for **18**, was crystallized from CH_2Cl_2 to give **19**: 69%, black fine prisms from CH_2Cl_2, mp 143—144 °C; IR 1650, 1640, 1600, 1580 cm^{-1}; UV λ_{max} (EtOH) 290 (log ε, 4.60), 352(3.65), 370(3.74), 390 (3.64), 544(2.59); NMR(CCl_4) 1.37 (3H, t, J=7 Hz), 4.30 (2H, q, J=7 Hz), 6.32 (1H, d, J=9 Hz), 7.17 (1H, d, J= 9 Hz), 7.36 (1H, s), 7.40—7.70 (3H, m, aromatic H), 7.99 (1H, d, aromatic H). Found: C, 59.58; H, 3.86; N, 4.54%. Calcd for $C_{15}H_{12}NOBr$: C, 59.60; H, 3.97; N, 4.64%.

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